

Introducing Remark

In early days of QM intense discussion of philosophical issues (the analysis of concepts, principles and ultimate presuppositions) of the theory. This culminated in 1935 with EPR debate between Einstein and Bohr. Bohr (and Copenhagen interpretation) were officially declared the winners. Bohr reigned supreme until the 1960s, except for the efforts of Bohm to construct h.v. models of QM. This was partly due to the influence of von Neumann, who gave theorem proved up the oft-cited Mathematical Foundations of Quantum Mechanics (1932).

Then technical advance and Gleason's theorem (1957) in principles and measures that could be applied and prediction rather of a Heisenberg's this theorem proved to be as they to the work of Bell and together and Specker (1967). A parallel development was the discovery of a non-locality property of h.v. theories in 1964. This was the Bell inequality which lead to many experimental tests culminating in the work of Aspect, Dalibard and Roger about to be discussed.

Not all different reactions from or believe physicists? Philosophers.

Aspect's result accepted by physicists regarded by many philosophers as revolutionary realist instrumentalist (substantial) interpretation of QM is not accepted. Philosophers want to understand

What we are going on in QM
to provide if you like A Quantum View of EPR

I am going to begin with the problem
of Non Locality

The problem situation here is that in
some sense the EPR phenomenon
in QM appears to modulate nonlocality,
instantaneous action at a distance, and
this is suffered by us to be ruled out
by special relativity.

By EPR phenomenon I mean the
correlation properties of spatially
separated systems in certain
states involving the superposition
of products of the particle wave functions
here as embodied by the singlet
spin wave function for two spin particles

$$P_{\text{singlet}} = \frac{1}{\sqrt{2}} (\alpha(1)\beta(2) - \beta(1)\alpha(2))$$

and the state with 2-component of spin $\pm \frac{1}{2} \hbar$
 $\beta \dots \dots \dots - - - \pm \frac{1}{2} \hbar$

This would describe for example the spins
of two protons emerging from a beta decay
(β wave) of scattering event (according to
the Pauli principle). Measuring the
spin-component of one particle apparently
changes the state of the other particle
in a non-local manner.

N.B. $2P_{sys}$ is a N.P. now broken, but it is the exact sum of the relativistic masses of the 2-body open box function related to an appropriate frame of reference for a slowly moving 2-body system

In order to proceed we distinguish 3 versions of the individual particle interpretation of QM called A, B & C.

This gives

3 mean an observer not in an aggregate

- A) Sharp unknown value
- B) Unsharp or 'fuzzy' value
- C) Undefined or meaningless value.

cp QM is not my favorite my favorite with new concepts like potentiality or latency, and my favorite in recognizing limitations in the applicability of old concepts.

3 mean a unit measurement do?

- A) Do-existing value revealed
- B) Potential or latent value actualized
- C) Undefined value becomes defined

How is this change brought about?

- 1) Interaction with a physical instrument
- 2) Action of human consciousness

The EPR Argument (1935)

This is an argument for the incompleteness of QM.

EPR takes as necessary condition for

Completeness: Every element of reality
has a counterpart in the theory, associated
with it.

They take as sufficient condition for

an element of reality: If without disturbing

a system we can predict with certainty
the values of an observable that
already, before the prediction, etc
exists an element of reality corresponding
to that observable.

The EPR argument is based on point B
and shows that this view is incompatible
in the sense that even in non-quantum
observables do have sharp values (not allowed
to in point B).

So the argument reduces us to turn to
Point A.

But the argument involves a locality
assumption

Locality: Unsharp \rightarrow sharp prediction

Disturbant Bell and Faster \rightarrow than of it should.

Bofri's response to EPR was to query whether we know not well what we know

C and we

Locality: undefined \rightarrow defined
'at-a-distance' freedom

But does this freedom could be denied since
no physical non-locality involved.

EPR showed that

QM + Locality, \rightarrow Incompatibility
(assuming non-B)

or QM \rightarrow Non-locality, \supset Incompatibility

Then is the Einstein demand ^{posed} \rightarrow non-locality
But Bell showed (1964) { ^{QM} _{Non-locality leads to the} \rightarrow EPR paradox

Completion \rightarrow non-locality₃
(non-B)

where:

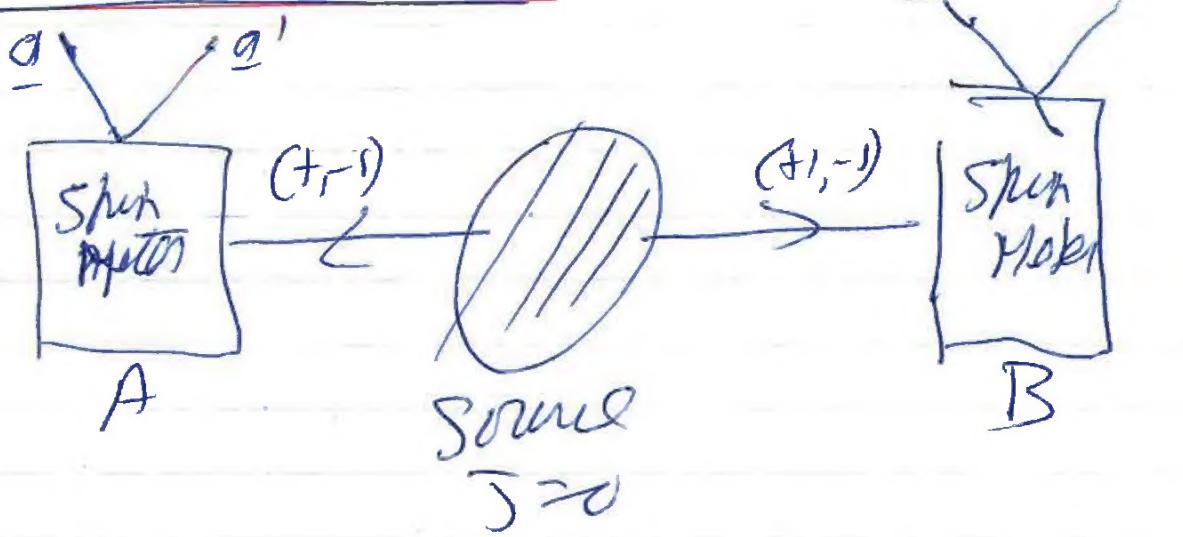
Locality₃ sharp \rightarrow sharp
at-a-distance freedom

The Bell Argument

Locality₃ \rightarrow Bell inequality
which is contradicted by
QM (and by experiment)

of a Particular Aspect, Dalibard and
Roger (P.R.L. 1982)

The Bell Experiment



a_n denotes spin-component of n -particle parallel to direction \underline{a}_1 for n^{th} pair of particles formed a_n', b_n, b_n' .

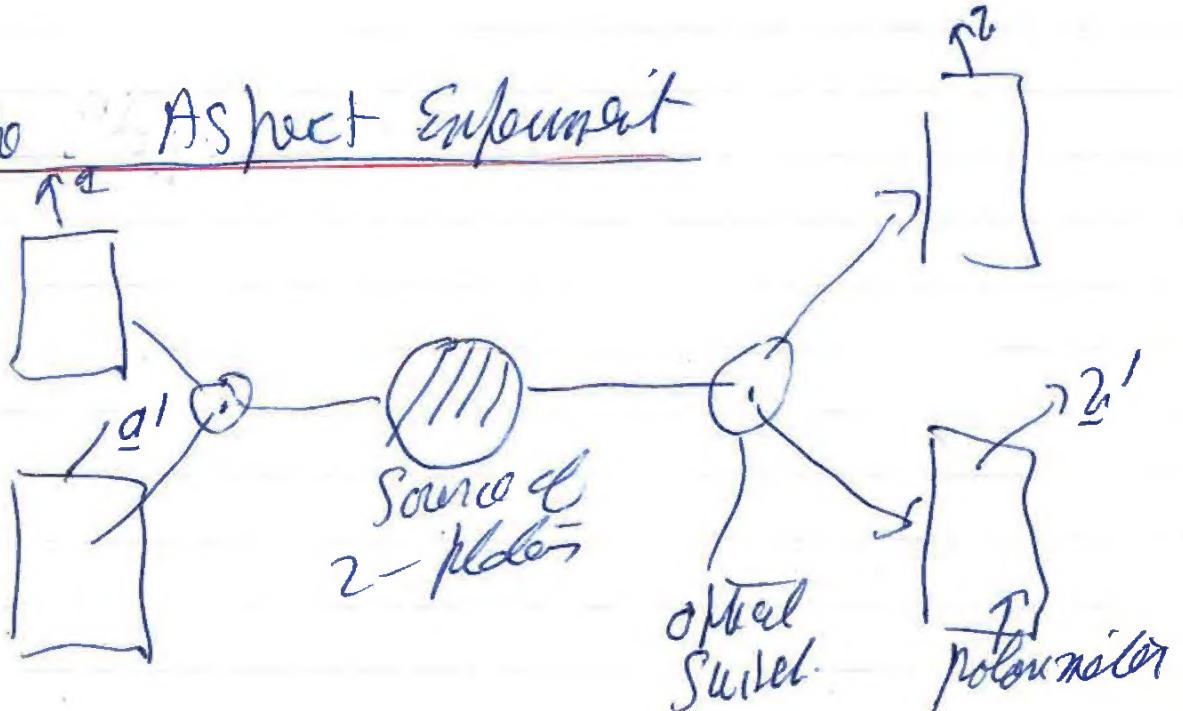
then defines correlation coefficients

$$c(a, b) = \frac{1}{N} \sum_n a_n b_n, \text{ etc}$$

The Bell Inequality reads

$$|c(a, b) + c(a', b) + c(a', b') - c(a, b')| \leq 2.$$

The Aspect Experiment



The Stapp-Eckhard Approach

Can we reformulate argument for Bell's Inequality in terms of measurement results, so it would apply also to user B.

Locality₄: Classical state of macroscopic object count, & altered at-a-distance.

The Principle of Local Counterfactual Definiteness (PLCD)

Result of an unperformed experiment has a definite result which does not depend on the setting of a remote piece of apparatus.

(So $\neg \text{PLCD} \rightarrow \neg \text{Loc}_4$ for Stapp-Bell)

But in a genuinely indeterministic situation (or in user B) PLCD is upheld.

Contrast a) clock striking at 9 o'clock and b) rain after days on a racing track.

Even if same experiment is performed twice \neg experiment gives different result (counterfactuals).

Statistical Nonlocality

No statistical effects produced at a distance - passing information at the wrong location - folded letters, roses in Chelsea example.

- Impossibility of Bell Telephone

Nonlocality violated in FPA?

		loc ₁	loc ₂	loc ₃	loc ₄	loc ₅
		User	loc ₁	loc ₂	loc ₃	loc ₄
User	loc ₁	no	no	yes	yes	no
	loc ₂	yes	no	no	no	no
		loc ₃	no	yes	no	no
		loc ₄	no	no	no	no
		loc ₅	no	no	no	no

N.B. Locality problem does not give in statistical or empirical
affirmed since loc₅ not violated

Does Violation of Locality conflict
with S.R.?

Violation of loc₃ more serious than loc₁,
cf Shimony (1973) pacifist General in
case of violation of loc₁.

Does S.R. prohibit entanglement effects
Topological theory, Causal Loop Paradox

Kochen-Specker Paradox

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So what comes from non-locality and can retain realism. But can we? There is another difficulty now for realism ~~in the~~ to the Kochen-Specker paradox. They demonstrated a purely algebraic problem about attribute values to observables.

Kochen-Specker showed the following.

view A + ~~FUNC~~ + (FUNC) \Rightarrow contradiction.

[VR says. $P_\phi^\phi(\lambda) = 0 \Rightarrow \{\phi\}^\phi \neq \lambda.$]

FUNC says. If \hat{A} and \hat{B} (furnished by FM.) are two operators and there exists a function $f: \mathbb{R} \rightarrow \mathbb{R}$
 $\hat{A} = f(\hat{B})$ then

$$\{\hat{A}\}^\phi = f(\{\hat{B}\}^\phi)$$

$$10. \quad \{\hat{f}(\hat{B})\}^\phi = f(\{\hat{B}\}^\phi).$$

Proof relies on FUNC holding for

$$\hat{A} = f(\hat{B}), \quad \hat{A} = g(\hat{C}) \quad \{\hat{B}, \hat{C}\} \neq 0.$$

$$\begin{aligned} \text{So } \{\hat{A}\}^\phi &= f(\{\hat{B}\}^\phi) \\ &= g(\{\hat{C}\}^\phi) \quad - \text{constraint} \\ &\quad \text{on value for} \\ &\quad \text{incompatible observables.} \end{aligned}$$

N.B. If $\{\hat{B}\}^\phi$ are maximal, \hat{A} must be degenerate for the situation to arise.

~~Extension~~
* Extension of rotators to two separated systems:

$$[Q \times I]^4_{\{A, B\}} (D, E)$$

We can break FUNC and retain
realism by supposing that the
each Σ_B generates two components
there are the magnetons

Now we designate A_B , A_c

$$[A_B]^\phi = f(\Sigma_B^\phi)$$

$$[A_c]^\phi = g(\Sigma_c^\phi)$$

In general we shall assume FUNC*
which says. effectiveness

$$A_B = A_c, \text{ if } \vec{B}, \vec{c} \text{ do not commute}$$

measured separately
i.e. $\exists g$ st. $g = g(B)$
 $g \circ f = 1$

Denote by $\{B\}$ equivalence class of
all B s.t. $\exists g$ st. $g = g(B)$

$$\text{Now we write } [A]_{\Sigma_B}^\phi = \{A_B\}^\phi$$

N.B. FUNC* is consistent with and
independent of VR.

This expresses Methodological Contextuality

But the value $[A]_{\Sigma_B}^\phi$ may also
depend on the environment, in particular
the operators set to measure some
magnetons c

$$\text{So we write } \Sigma_B^\phi(c)$$

Now we express Environment-Dependent Contextuality

* inert

We now apply these notions to
two separated systems

For all Q, A, B, C, D, E , where $Q = h(A)$ and
 A, B, C, D and E are all maximal

$$\begin{aligned} \text{OLEC} \\ \overrightarrow{[Q \otimes I]}_{\{(A, B)\}}^{\phi} (D, E) \\ = \overrightarrow{[Q \otimes I]}_{\{(A, C)\}}^{\phi} (D, E) \end{aligned}$$

$$\text{ELOC} \\ \overrightarrow{[Q \otimes I]}_{\{(A, B)\}}^{\phi} (D, E) = \overrightarrow{[\phi \otimes I]}_{\{(A, B)\}}^{\phi} (D, E)$$

where $\langle A, B \rangle$ is the maximal physical
magnitudes for the first system
where created under $\langle A \rangle$ and $\langle B \rangle$ is created
under $\langle B \rangle$ the weaker

$$\vec{D} = \sum_{i,j} c_{i,j} \vec{P}_i \otimes \vec{D}'_j$$

$$\text{where } \vec{A} = \sum_i \vec{P}_i, \quad \vec{B} = \sum_j \vec{P}'_j \\ \text{and } c_{i,j} = F(\alpha_i, \beta'_j) \text{ where } F: \mathbb{R}^2 \rightarrow \mathbb{R} \text{ is 1:1}$$

In words -

OLEC locally maximal physical magnitudes
in a set of two spatially separated
systems are not split, they
are global, contextually related to
the specification of different maximal
physical magnitudes for the first system

FLO^c: the value possessed by a local physical magnitude cannot be changed by altering the arrangement of a remote piece of apparatus which forms part of its measurement context for the combined system.

VB ① do not generalise DLO in specifying FLO^c but FLO^c is only properly local if parallel to DLO of areas.

② In terms of Measurement results DLO \neq FLO. but meanwhile a dependence of outcome recorded by apparatus connected to the system on the setting of the apparatus connected to the other (remote) system.

Redhead - Heywood result

We shall show that

* $F_{\text{VR}}^{\text{a}} \rightarrow \text{VR} \rightarrow \text{FLO} \rightarrow \text{DLO}$
 \rightarrow Contradiction

Before Value Rule VR $\rightarrow \int_Q^{\phi}(A) = 0 \rightarrow \int_Q \phi^{\phi} \neq 0$. (R.K.-S type)
Preliminary Comments

Proofs. of nonlocality via Bell Inequality have been charged with 'hidden' assumptions. As Foul remarks (1974) 'Hidden variables are, as they, hidden assumptions another'.

Fine has claimed (1974) that Bell's original type of prof. involved FUNC in the form of the Product Rule (JD) assumption that QM joints and phase-spec joints were identical.)
 Anyway fine said we are committed to joint distributions for non-commuting observables even in the Eberhard type of prof. (1982) (In h.v. approach this is true)
But fine is wrong here.

Bell \rightarrow Kolm-joints
 Kolm-joints \rightarrow self joints in a model.
 But this model need not be the real world!

However all prof. of non-locality via Bell's theorem do involve non-locality of probabilities theory that must be challenged.

Query Can we give a reality definite locality?

Question posed by Bell (1976) can be form:

Is it possible to extend Haag's theorem (1971) to locally material observables?

M's theorem says we do not need ontological content to allow valid assignments to maximal observables.

M's theorem cannot be extended this would mean locally material observables must be ontologically contentful \Rightarrow violation of QM

Unfortunately Demopoulos, Bob, Humphreys
have shown that H's electrons
can be extended to local Maxwell
formulation.

So DLG need not be violated

On next page however that if
we let obtain Fene's VR then
OLG or ELOG is with most far.

Violating DLG means we cannot
specify a locally maximal observable
independently of properties relating to
the whole combined system
— leads to at odds holism in which
it is impossible to make sense of
a realist construction of it flat out
properties and parts with local &
non separated systems with local &

Violating ELOG (if DLG is assumed)
is the fact of New Zealand envisaged
in the Bell-type non-local arguments.

The steps in the proof are as follows:

1.) Derive CVR from $2R$ and F_{air}^*

evA \mathcal{B}_1 ad \mathcal{B}_2 commutes and \mathcal{B}_1 is
 maximal operator s.t. $\mathcal{B}_1 = f(A)$, $\mathcal{B}_2 = g(A)$

$$\text{Def. } P_{Q_1, Q_2}^{\Phi}(\lambda, \mu) = 0 \Rightarrow \Phi$$

$$[\delta_1]_{\Sigma_{\mathcal{A}_1}}^\phi (R) \neq \lambda$$

$$\alpha \in [0, 3]_{\mathbb{R}}^{\phi} (R) \text{ for } \cdot$$

N.B. EVR. for several commutes θ_1, θ_2
is not available from VTR as for θ^*
ad. \Rightarrow FVR, which contradicts
Res was forced to, for on 1974.

2.) As a special case, if $\phi = h(\bar{A}) \oplus h(\bar{B})$ are obtainable, then $\bar{A} = h(\bar{A})$, $\bar{B} = h(\bar{B})$ when A, B are maximal.
 $P_{Q \otimes I, I \otimes Q}^\phi(x, y) = 0$
 $\Rightarrow [Q \otimes I]_{\{(A, B)\}}^\phi(A, B) \neq x$
 $\text{or } [I \otimes Q]_{\{(A, B)\}}^\phi(A, B) \neq y$

Incompatibility of eVA and Locality

Consider Calculated plots of 2 separated

$$\text{Options} \quad \tilde{H} = \sum C_m \left(|d_m\rangle\langle d_m| \right)$$

$\hat{A} = C \otimes I_m \otimes I_n$
 \hat{A} has eigenvalues $\alpha_1, \dots, \alpha_N$
 \hat{B} β_1, \dots, β_N

Consider non-normal operator \hat{Q} s.t.
 $Q = f(\hat{A}) = g(\hat{A}')$ for measure \hat{A}, \hat{A}'
 where $[\hat{A}, \hat{A}'] \neq 0$.

Then it is easy to show that

$$[A \otimes I]_{\{(A, B)\}}^4 (A, B) = \alpha_m \quad (1)$$

$$\Rightarrow [I \otimes B]_{\{(A, B)\}}^4 (A, B) = \beta_m.$$

and $[I \otimes B]_{\{(A', B)\}}^4 (A', B) = \beta_m$

$$\Rightarrow [F(A \otimes I)]_{\{(A', B)\}}^4 (A', B) = f(\alpha_m) \quad (2)$$

Now apply Eloc & Sloc to equate

$$[I \otimes B]_{\{(A, B)\}}^4 (A, B) = [I \otimes B]_{\{(A', B)\}}^4 (A', B)$$

where we obtain FUNC **

$$[F(A \otimes I)]_{\{(A', B)\}}^4 (A', B) \\ = f([A \otimes I]_{\{(A, B)\}}^4 (A, B))$$

This is not quite FUNC since we
 have soil environmental constraint
 (not solid or).

But can we be wed to demerit
 a T-S TQ contradiction by following
 their argument parallel to that used by T-S
 in their note of 2 next main in their 1967 paper

Comments

1.) Fine (1977) and Stairs (1978) claimed CVR was contradictory

But we have derived CVR as a theorem from VR and Fove*

Explanation CVR would be contradictory if we did not allow for violation of locality - this is clear in the work of Fine and Stairs

2.) Mineral's transparency are of probability they - On user A & H is non-local

3.) What about Stockart's h.v.-steves
Here measurement results are stockartites
related to the hidden state of
the microsystem (so FM is given up)
The Eberhard-type proof now fails
because of P(c)⁰ being inapplicable.
VR is not applicable to our
approach for not being

Bell Theorem can be proved if no locality
locality = locality

Perhaps we just have to give up locality -
- cf. Fine.

Final remark

Interaction of Physics and Philosophy

- either 1) Physics should be changed in the light of philosophical considerations
- or 2.) Philosophical ideas should be modified in the light of new theories in physics

Role of Philosophy of Physics or of
 Philosophy is to show what
 total packages are available —
 when choice is matter for argument
 but not decisively settleable.

~~(Ideal book on Physics) - sub (a)~~
 The role of Philosophy on Physics then is
 to promote understanding of what
 Physics really is committting to

of course theoretical physicists do use
 philosophical analysis of a sort in their
 work — Einstein and Bohr are notable
 examples. However in the case of Einstein
 general relativity notoriously fails to
 implement his philosophy, while Bohr gives
 us a very unclear mesh-mash of
 Kierkegaard, Kant and Hegel's work,
 to mention some of his sources.

But the surprising thing is that
 modified philosophy is quite consistent
 with splendid physics.

In a sense one could claim that
 Einstein did not understand Relativity

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nr Bohr quantum mechanics, but
then one can do physics without
understanding it rather like riding
a bicycle without knowing anything
about rigid-body dynamics.
But how much better to do
physics and understand it to
combine the study of physics
with the study of philosophy of
physics
